

What Is Claimed Is:

1 1. A method for I/Q mismatch calibration of a
2 transmitter, comprising the following steps:
3 generating a discrete-time signal $x[n]=x(n \cdot T_s)$, wherein
4 $x(t)=e^{j2\pi f_T t}$ and f_T and T_s are real numbers;
5 obtaining a corrected signal $x_c[n]$ based on the signal $x[n]$
6 and a set of correction parameters A_p and B_p , wherein
7 $x_c[n]=A_p \cdot x[n]+B_p \cdot x^*[n]$;
8 converting the corrected signal $x_c[n]$ to an analog
9 corrected signal $x_c(t)$;
10 applying I/Q modulation to the analog corrected signal
11 $x_c(t)$ and outputting a modulated signal $x_m(t)$;
12 obtaining a first desired component measure $W^{(1)}(f_T)$ and a
13 first image component measure $W^{(1)}(-f_T)$ from the
14 modulated signal $x_m(t)$ with a first set of the
15 correction parameters A_p and B_p ;
16 obtaining a second desired component measure $W^{(2)}(f_T)$ and
17 a second image component measure $W^{(2)}(-f_T)$ from the
18 modulated signal $x_m(t)$ with a second set of the
19 correction parameters A_p and B_p ;
20 obtaining a third desired component measure $W^{(3)}(f_T)$ and a
21 third image component measure $W^{(3)}(-f_T)$ from the
22 modulated signal $x_m(t)$ with a third set of the
23 correction parameters A_p and B_p ;
24 obtaining a fourth and fifth set of correction parameters
25 A_p and B_p based on the first, the second, and the third
26 desired component measures as well as the first, the
27 second, and the third image component measures;

28 obtaining a fourth desired component measure $W^{(4)}(f_T)$ and
29 a fourth image component measure $W^{(4)}(-f_T)$ from the
30 modulated signal $x_m(t)$ with the fourth set of
31 correction parameters A_p and B_p ;
32 obtaining a fifth desired component measure $W^{(5)}(f_T)$ and a
33 fifth image component measure $W^{(5)}(-f_T)$ from the
34 modulated signal $x_m(t)$ with the fifth set of
35 correction parameters A_p and B_p ; and
36 obtaining a final set of the correction parameters A_p and
37 B_p from the fourth and fifth sets of correction
38 parameters.

1 2. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 1, wherein the first set of
3 correction parameters $(A_p, B_p) = (a, 0)$, the second set of
4 correction parameters $(A_p, B_p) = (b, b)$, and the third set of
5 correction parameters $(A_p, B_p) = (b, -b)$, where a and b are real
6 numbers.

1 3. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 2, wherein the parameter a is
3 1 and the parameter b is $1/2$.

1 4. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 1, wherein the fourth set of
3 correction parameters (A_p, B_p) are obtained by

4
$$A_p = \sqrt{P} - j\hat{\alpha}\sqrt{Q}$$
$$B_p = -\hat{\alpha}\sqrt{P} - j\sqrt{Q}$$

5 and the fifth set of correction parameters (A_p, B_p) are
6 obtained by

$$\begin{aligned} A_p &= \sqrt{P} + j\hat{\alpha}\sqrt{Q} \\ B_p &= -\hat{\alpha}\sqrt{P} + j\sqrt{Q} \end{aligned}$$

where

$$\alpha \approx \hat{\alpha} = \frac{\sqrt{N/O} - 1}{\sqrt{N/O} + 1} ,$$

$$N = (W^{(2)}(f_T) + W^{(2)}(-f_T)) / 2 ,$$

$$O = (W^{(3)}(f_T) + W^{(3)}(-f_T)) / 2 ,$$

$$Q = \frac{\hat{\alpha}^2 - \rho^{(1)}}{(1 + \rho^{(1)})(\hat{\alpha}^2 - 1)} ,$$

$$P = 1 - Q ,$$

$$\rho^{(1)} = \frac{W^{(1)}(-f_T)}{W^{(1)}(f_T)} .$$

5. The method for I/Q mismatch calibration of a transmitter as claimed in claim 1, wherein the final set of correction parameters (A_p, B_p) is set to be the fourth set of correction parameters if a function of $W^{(4)}(-f_T)$ is less than the function of $W^{(5)}(-f_T)$, otherwise the final set of correction parameters (A_p, B_p) is set to be the fifth set of correction parameters.

6. The method for I/Q mismatch calibration of a transmitter as claimed in claim 5, wherein the final set of correction parameters (A_p, B_p) is set to be the fourth set of correction parameters if $W^{(4)}(-f_T)$ is less than $W^{(5)}(-f_T)$, otherwise the final set of correction parameters (A_p, B_p) is set to be the fifth set of correction parameters.

1 7. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 1, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if a function of $W^{(4)}(f_T)$ is greater than
5 the function of $W^{(5)}(f_T)$, otherwise the final set of correction
6 parameters (A_p, B_p) is set to be the fifth set of correction
7 parameters.

1 8. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 7, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if $W^{(4)}(f_T)$ is greater than $W^{(5)}(f_T)$,
5 otherwise the final set of correction parameters (A_p, B_p) is set
6 to be the fifth set of correction parameters.

1 9. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 1, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if a function of $W^{(4)}(-f_T)$ and $W^{(4)}(f_T)$ is
5 less than the function of $W^{(5)}(-f_T)$ and $W^{(5)}(f_T)$, otherwise the
6 final set of correction parameters (A_p, B_p) is set to be the fifth
7 set of correction parameters.

1 10. The method for I/Q mismatch calibration of a
2 transmitter as claimed in claim 9, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if $W^{(4)}(-f_T)/W^{(4)}(f_T)$ is less than
5 $W^{(5)}(-f_T)/W^{(5)}(f_T)$, otherwise the final set of correction
6 parameters (A_p, B_p) is set to be the fifth set of correction
7 parameters.

11. The method for I/Q mismatch calibration of a transmitter as claimed in claim 1, further comprising the following steps:

further adding an DC compensation parameter γ_p while obtaining the corrected signal $x_c[n]$ such that
$$x_c[n] = A_p \cdot (x[n] + \gamma_p) + B_p \cdot (x[n] + \gamma_p)^* ;$$

obtaining a first local leakage component measure L_1 from the modulated signal $x_m(t)$ with the final set of parameters A_p and B_p , and the parameter $\gamma_p = \zeta_1$, where ζ_1 is a real number;

obtaining a second local leakage component measure L_2 from the modulated signal $x_m(t)$ with the final set of parameters A_p and B_p , and the parameter $\gamma_p = \zeta_2$, where ζ_2 is a real number;

obtaining a third local leakage component measure L_3 from the modulated signal $x_m(t)$ with the final set of parameters A_p and B_p , and the parameter $\gamma_p = j\zeta_1$;

obtaining a fourth local leakage component measure L_4 from the modulated signal $x_m(t)$ with the final set of parameters A_p and B_p , and the parameter $\gamma_p = j\zeta_2$;

obtaining a fifth local leakage component measure L_5 from the modulated signal $x_m(t)$ with the final set of parameters A_p and B_p , and the parameter $\gamma_p = 0$; and

obtaining a final DC compensation parameter $\gamma_{p,final}$ based on the first local leakage component measure L_1 , the second local leakage component measure L_2 , the third local leakage component measure L_3 , the fourth local leakage component measure L_4 and the fifth local leakage component measure L_5 .

12. The method for I/Q mismatch calibration of a transmitter as claimed in claim 11, wherein the final DC compensation parameter $\gamma_{p,final}$ is obtained by

$$\gamma_{p,final} = -\frac{1}{2} \cdot \frac{\zeta_2^2(L_1 - L_5) - \zeta_1^2(L_2 - L_5)}{\zeta_1(L_2 - L_5) - \zeta_2(L_1 - L_5)} - j \frac{1}{2} \cdot \frac{\zeta_2^2(L_3 - L_5) - \zeta_1^2(L_4 - L_5)}{\zeta_1(L_4 - L_5) - \zeta_2(L_3 - L_5)}.$$

13. An apparatus for I/Q mismatch calibration of a transmitter, comprising:

a signal generator for generating a discrete-time signal $x[n] = x(n \cdot T_s)$, wherein $x(t) = e^{j2\pi f_T t}$ and f_T and T_s are real numbers;

a correction module for receiving the discrete-time signal $x[n]$ and obtaining a corrected signal $x_c[n]$ based on the test signal $x[n]$ and a set of correction parameters A_p and B_p , wherein $x_c[n] = A_p \cdot x[n] + B_p \cdot x^*[n]$;

a first and second D/A converter converting the corrected signal $x_c[n]$ to an analog signal $x_c(t)$, wherein the first D/A converter converts the real part of the corrected signal to the real part of the analog signal, and the second D/A converter converts the imaginary part of the corrected signal to the imaginary part of the analog signal;

a modulator applying I/Q modulation to the analog signal $x_c(t)$, and outputting a modulated signal $x_m(t)$;

a measurer for implementing the steps of:

obtaining a first desired component measure $W^{(1)}(f_T)$ and a first image component measure $W^{(1)}(-f_T)$ from the modulated signal $x_m(t)$ with a first set of the correction parameters A_p and B_p ;

24 obtaining a second desired component measure $W^{(2)}(f_T)$
25 and a second image component measure $W^{(2)}(-f_T)$
26 from the modulated signal $x_m(t)$ with a second
27 set of the correction parameters A_p and B_p ;
28 obtaining a third desired component measure $W^{(3)}(f_T)$
29 and a third image component measure $W^{(3)}(-f_T)$
30 from the modulated signal $x_m(t)$ with a third set
31 of the correction parameters A_p and B_p ;
32 obtaining a fourth desired component measure
33 $W^{(4)}(f_T)$ and a fourth image component measure
34 $W^{(4)}(-f_T)$ from the modulated signal $x_m(t)$ with a
35 fourth set of correction parameters A_p and B_p ;
36 and
37 obtaining a fifth desired component measure $W^{(5)}(f_T)$
38 and a fifth image component measure $W^{(5)}(-f_T)$
39 from the modulated signal $x_m(t)$ with a fifth set
40 of correction parameters A_p and B_p ; and
41 a processor for implementing the steps of:
42 obtaining the fourth and fifth sets of correction
43 parameters A_p and B_p based on the first, the
44 second, and the third desired component
45 measures as well as the first, the second, and
46 the third image component measures; and
47 choosing a final set of correction parameters A_p and
48 B_p from the fourth and fifth sets of correction
49 parameters.

1 14. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the first set of
3 correction parameters $(A_p, B_p) = (a, 0)$, the second set of

4 correction parameters $(A_p, B_p) = (b, b)$, and the third set of
5 correction parameters $(A_p, B_p) = (b, -b)$, where a and b are real
6 numbers.

1 15. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the parameter a is
3 1 and the parameter b is $1/2$.

1 16. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the fourth set of
3 correction parameters (A_p, B_p) are obtained by

$$\begin{aligned} A_p &= \sqrt{P} - j\hat{\alpha}\sqrt{Q} \\ B_p &= -\hat{\alpha}\sqrt{P} - j\sqrt{Q} \end{aligned}$$

5 and the fifth set of correction parameters (A_p, B_p) are
6 obtained by

$$\begin{aligned} A_p &= \sqrt{P} + j\hat{\alpha}\sqrt{Q} \\ B_p &= -\hat{\alpha}\sqrt{P} + j\sqrt{Q} \end{aligned}$$

8 where

$$\alpha \approx \hat{\alpha} = \frac{\sqrt{N/O} - 1}{\sqrt{N/O} + 1},$$

$$N = (W^{(2)}(f_T) + W^{(2)}(-f_T)) / 2,$$

$$O = (W^{(3)}(f_T) + W^{(3)}(-f_T)) / 2,$$

$$Q = \frac{\hat{\alpha}^2 - \rho^{(1)}}{(1 + \rho^{(1)})(\hat{\alpha}^2 - 1)},$$

$$P = 1 - Q,$$

$$\rho^{(1)} = \frac{W^{(1)}(-f_T)}{W^{(1)}(f_T)}.$$

1 17. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if a function of $W^{(4)}(-f_T)$ is less than the
5 function of $W^{(5)}(-f_T)$, otherwise the final set of correction
6 parameters (A_p, B_p) is set to be the fifth set of correction
7 parameters.

1 18. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 17, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if $W^{(4)}(-f_T)$ is less than $W^{(5)}(-f_T)$,
5 otherwise the final set of correction parameters (A_p, B_p) is set
6 to be the fifth set of correction parameters.

1 19. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if a function of $W^{(4)}(f_T)$ is greater than
5 the function of $W^{(5)}(f_T)$, otherwise the final set of correction
6 parameters (A_p, B_p) is set to be the fifth set of correction
7 parameters.

1 20. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 19, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if $W^{(4)}(f_T)$ is greater than $W^{(5)}(f_T)$,
5 otherwise the final set of correction parameters (A_p, B_p) is set
6 to be the fifth set of correction parameters.

1 21. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if a function of $W^{(4)}(-f_T)$ and $W^{(4)}(f_T)$ is
5 less than the function of $W^{(5)}(-f_T)$ and $W^{(5)}(f_T)$, otherwise the
6 final set of correction parameters (A_p, B_p) is set to be the fifth
7 set of correction parameters.

1 22. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 21, wherein the final set of
3 correction parameters (A_p, B_p) is set to be the fourth set of
4 correction parameters if $W^{(4)}(-f_T)/W^{(4)}(f_T)$ is less than
5 $W^{(5)}(-f_T)/W^{(5)}(f_T)$, otherwise the final set of correction
6 parameters (A_p, B_p) is set to be the fifth set of correction
7 parameters.

1 23. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 13, wherein the processor
3 further implementing the steps of:

4 further adding an DC compensation parameter γ_p while
5 obtaining the corrected signal $x_c[n]$ such that

$$x_c[n] = A_p \cdot (x[n] + \gamma_p) + B_p \cdot (x[n] + \gamma_p)^* ;$$

7 obtaining a first local leakage component measure L_1 from
8 the modulated signal $x_m(t)$ with the final set of
9 parameters A_p and B_p , and the parameter $\gamma_p = \zeta_1$, where
10 ζ_1 is a real number;

11 obtaining a second local leakage component measure L_2 from
12 the modulated signal $x_m(t)$ with the final set of
13 parameters A_p and B_p , and the parameter $\gamma_p = \zeta_2$, where
14 ζ_2 is a real number;

15 obtaining a third local leakage component measure L_3 from
16 the modulated signal $x_m(t)$ with the final set of
17 parameters A_p and B_p , and the parameter $\gamma_p=j\zeta_1$;
18 obtaining a fourth local leakage component measure L_4 from
19 the modulated signal $x_m(t)$ with the final set of
20 parameters A_p and B_p , and the parameter $\gamma_p=j\zeta_2$;
21 obtaining a fifth local leakage component measure L_5 from
22 the modulated signal $x_m(t)$ with the final set of
23 parameters A_p and B_p , and the parameter $\gamma_p=0$; and
24 obtaining a final DC compensation parameter $\gamma_{p,final}$ based on
25 the first local leakage component measure L_1 , the
26 second local leakage component measure L_2 , the third
27 local leakage component measure L_3 , the fourth local
28 leakage component measure L_4 and the fifth local
29 leakage component measure L_5 .

1 24. The apparatus for I/Q mismatch calibration of a
2 transmitter as claimed in claim 23, wherein the final DC
3 compensation parameter $\gamma_{p,final}$ is obtained by

4
$$\gamma_{p,final} = -\frac{1}{2} \cdot \frac{\zeta_2^2(L_1 - L_5) - \zeta_1^2(L_2 - L_5)}{\zeta_1(L_2 - L_5) - \zeta_2(L_1 - L_5)} - j \frac{1}{2} \cdot \frac{\zeta_2^2(L_3 - L_5) - \zeta_1^2(L_4 - L_5)}{\zeta_1(L_4 - L_5) - \zeta_2(L_3 - L_5)}.$$